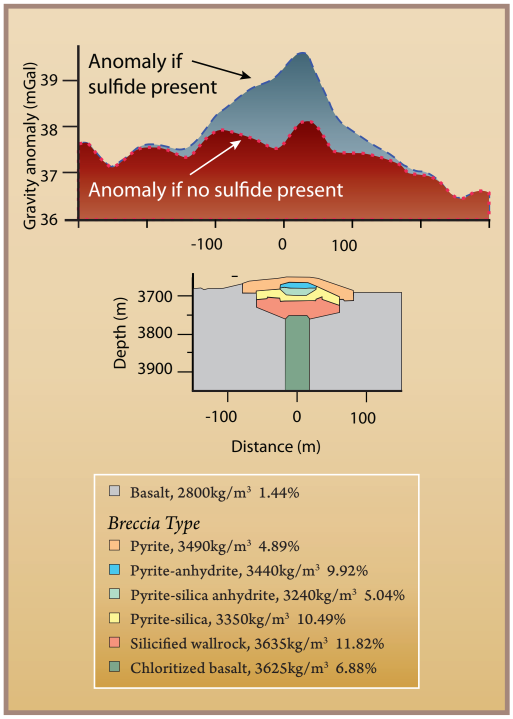
Gravity Measurements

Understanding the Structure of Shallow Oceanic Crust

Gravity measurements provide valuable information about the density and porosity of the sub-seafloor that can help us to better understand its structure. For example, gravity can be used to determine the size of potentially valuable metal-rich massive sulfide deposits on the seafloor. Currently, near-bottom gravity surveys primarily use on-bottom gravity measurements—where an instrument, or an instrument on a submersible, sits in a stationary position on the seafloor while obtaining data. These on-bottom measurements, while highly accurate, are time consuming. On a single dive, typically less than 10 measurements can be made.

The number of measurements could be significantly increased with continuous surveying; i.e., with gravity measured from a moving submersible operating near the seafloor. However this technique has been impractical because it requires *(i)* minimizing the vehicle's vertical and rotational motions; and *(ii)* obtaining accurate estimates of the residual vertical and rotational motion so that contributions from these motions can be subtracted from the gravity measurements.

My DOEI-supported research investigates the use of autonomous underwater vehicles (AUVs) to measure the gravity effect of density anomalies (such as metal-rich sulfide deposits) occurring within the seafloor. AUVs possess two advantages over other submersibles: precision depth control (to within 0.02 meters) and highly stable attitude performance (on the order of 0.1°), thus satisfying condition *(i)*. Challenge *(ii)*—accurately estimating the vehicle accelerations—requires exploiting recent advances in navigation sensing and research into improved algorithms (mathematical formulas) for navigating AUVs.



The larger gravity anomaly that would be measured from a moving AUV above a sulfide-rich mound similar in composition and size to an active mound (blue dashed line) compared to the lesser anomaly for a crust composed only of basalt (red dashed line). Densities and porosities assumed for each mound layer are shown. The sub-seafloor structure (shown below the anomalies) is a simplified version of Ocean Drilling Program results for the active TAG mound (from Humphris et al., Nature, *1995).*

To demonstrate our ability to measure gravity from AUVs, we developed a computer model of an active hydrothermal mound, creating a simplified depiction of its known sub-seafloor density structure. Using this depiction and actual dynamics data from the *Sentry* AUV, we computed synthesized gravimeter measurements that contain both the synthesized gravity measurements and the vehicle accelerations.

The next step was to see if a simple gravity filtering technique could be used on the synthesized AUV gravimeter measurements to remove the vehicle accelerations. While generation of the synthetic gravity measurements used precise information about vehicle depth, rotation and accelerations, the filtering technique considers current best estimates of vehicle accelerations given current abilities in navigation sensing.

Our results show that, using a simple gravity filtering technique, we can observe the increased gravity anomaly resulting from the dense sulfide minerals within the hydrothermal mound. Obtaining high-resolution gravity measurements in a cost- and time-effective manner could provide crucial information on the structure of shallow oceanic crust that is currently unavailable.

—James Kinsey